Digital Image Processing & Machine Vision

Image Morphology

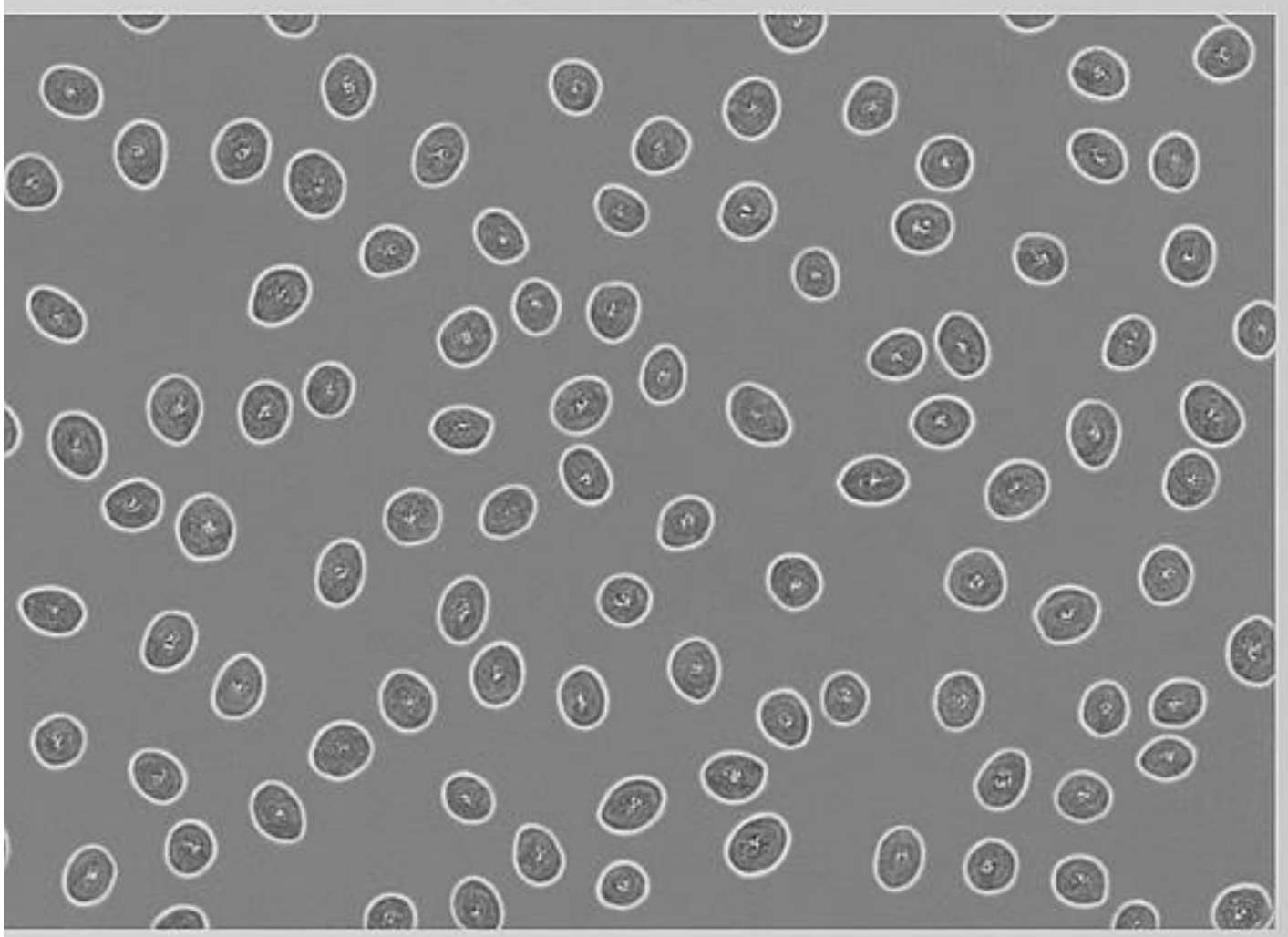
Lecture # 8

by Dr. Abdul Rehman Abbasi

Morphology; What?

- "Imagine you're an inspector in a textile factory. Thousands of fabric rolls pass before your eyes daily. You must spot even the tiniest tear or missing stitch. But what if the defect is so subtle that it blends into the fabric's pattern?
- You need a lens — not just a visual one — but a mathematical one, that can 'see' structure, shape, and absence.
- Welcome to Image Morphology."

Counting and Classifying Cells



Counting and Classifying Cells (Biomedicine)

- **Morphological operations** like erosion and dilation help isolate individual cells in microscopy images.
- Helps in diagnosing diseases, studying cell behavior, or screening for drugs.

Use open datasets (e.g., from Kaggle or NIH) to count cells or segment nuclei using morphological operations.

Kaggle Dataset Platform

https://www.kaggle.com/datasets/paultimothymooney/blood-cells

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871

Code

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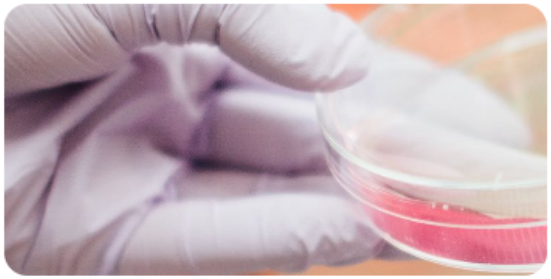
Blood Cell Images

12,500 images: 4 different cell types



Data Card | Code (168) | Discussion (10) | Suggestions (0)

About Dataset

Usability

7.06

NIH Chest X-Ray Dataset on Kaggle

NIH Chest X-rays

https://www.kaggle.com/datasets/nih-chest-xrays/data

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NATIONAL INSTITUTES OF HEALTH CHEST X-RAY DATASET AND
1 COLLABORATOR · UPDATED 7 YEARS AGO

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Code

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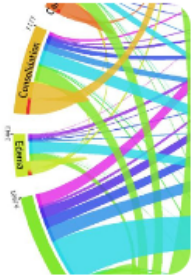
NIH Chest X-rays

Over 112,000 Chest X-ray images from more than 30,000 unique patients



Data Card | Code (579) | Discussion (25) | Suggestions (0)

About Dataset

Usability

7.35

hest X-rays

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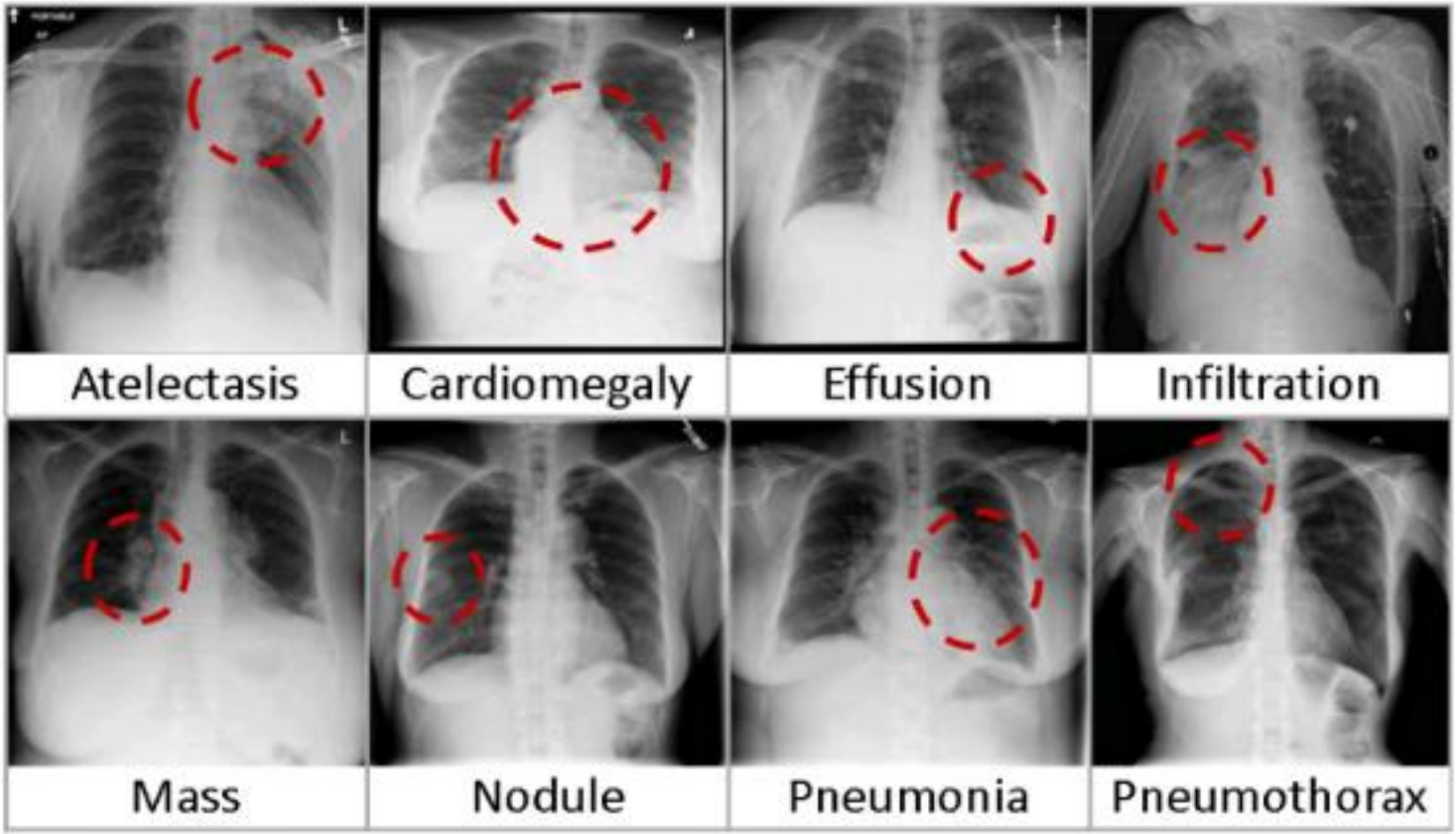
ird Code (579) Discussion (25) Suggestions (0)

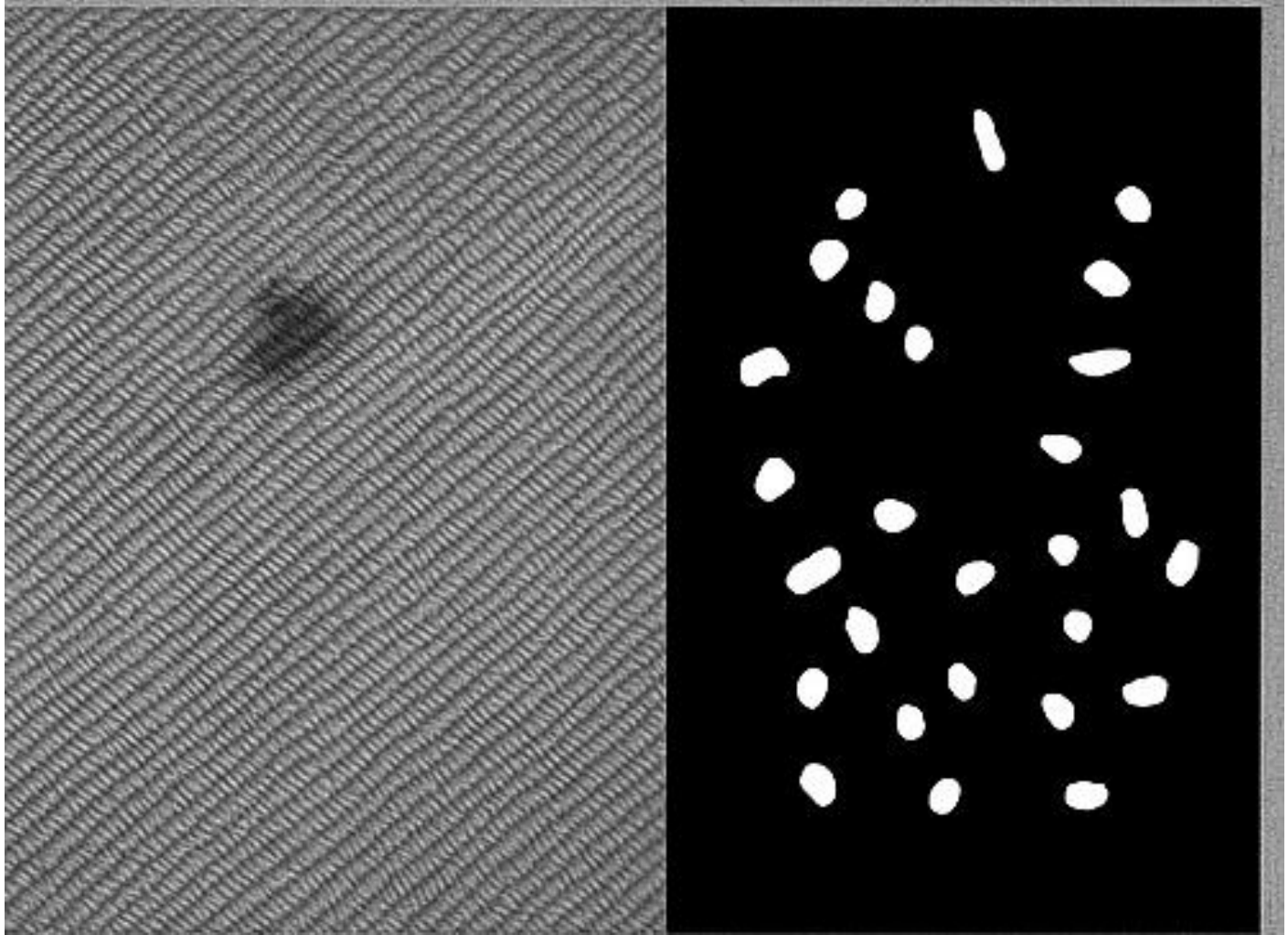
B. Eight visual examples of common thorax diseases



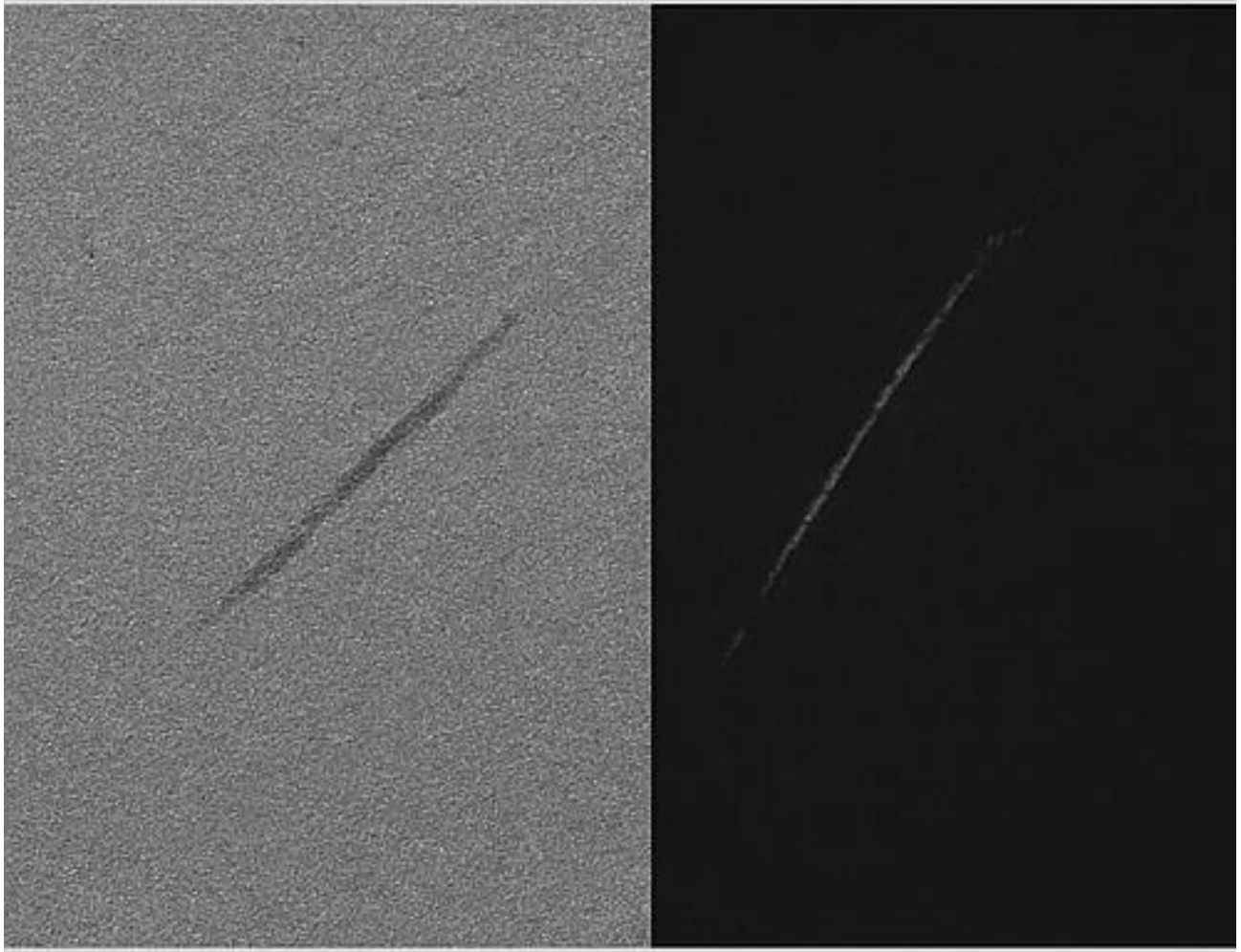
A.2 co-occurrence matrix of the fourteen thorax diseases in this chest X-ray dataset

4212	369	3269	3259	727	585	243	772	1222	221	423	220	495	40
369	1094	1060	583	99	108	36	48	169	127	44	51	111	7
3269	1060	3959	3990	1244	909	253	995	1287	592	359	188	848	21
3259	583	3990	9552	1151	1544	571	943	1220	979	447	345	749	33
727	99	1244	1151	2138	894	62	424	602	128	212	115	448	25
585	108	909	1544	894	2706	63	340	428	131	115	166	410	10
243	36	253	571	62	63	307	34	114	330	21	11	45	2
772	48	995	943	424	340	34	2199	222	33	746	80	289	9
1222	169	1287	1220	602	428	114	222	1314	162	103	79	251	4
221	127	592	979	128	131	330	33	162	634	30	9	64	3
423	44	359	447	212	115	21	746	103	30	895	36	151	4
220	51	188	345	115	166	11	80	79	9	36	727	176	8
495	111	848	749	448	410	45	289	251	64	151	176	1127	8
40	7	21	33	25	10	2	9	4	3	4	8	8	110
11535	2772	13307	19871	5746	6323	1353	5298	4667	2303	2516	1686	3385	227

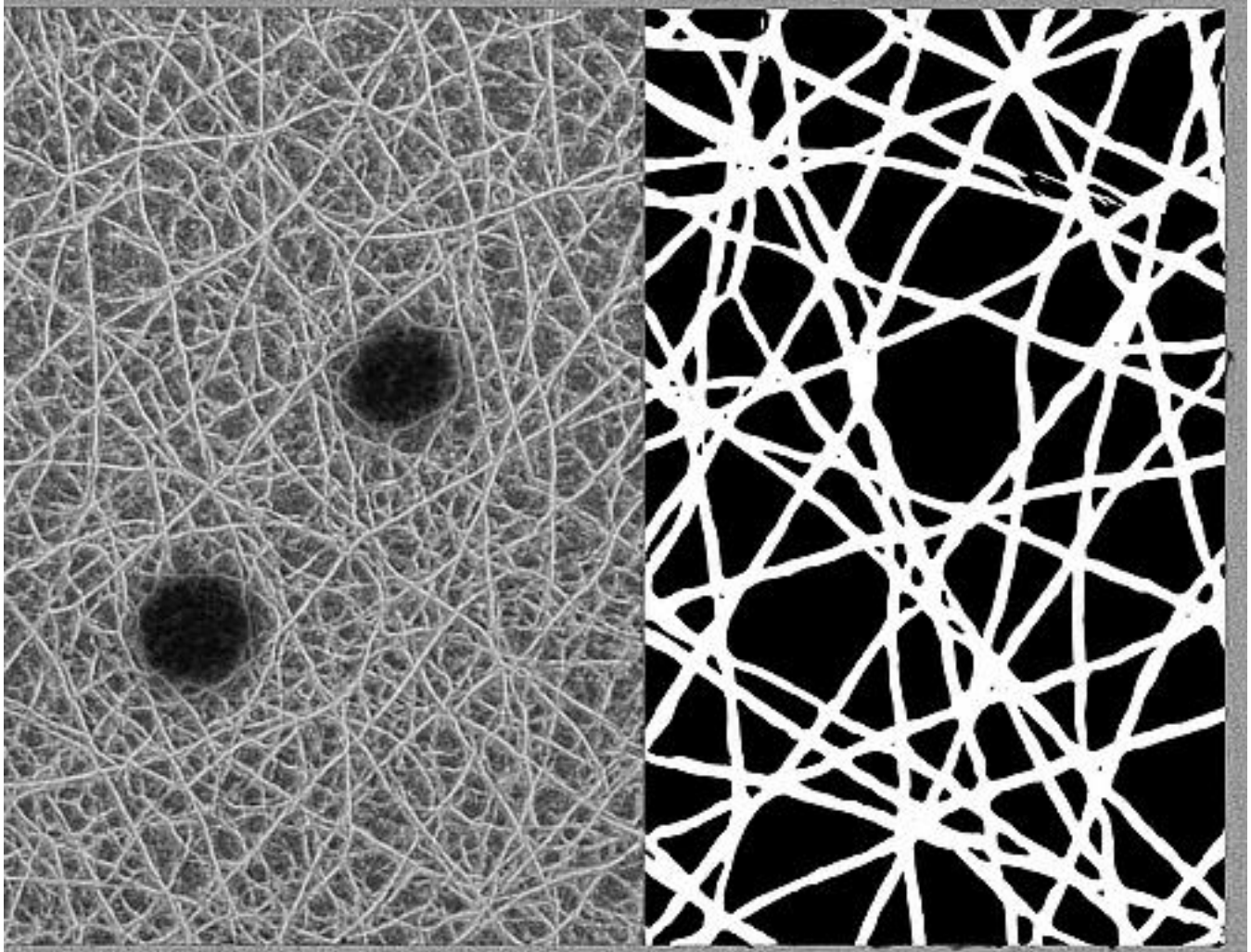
Defect Detection in Textiles



Surface Inspection of Materials

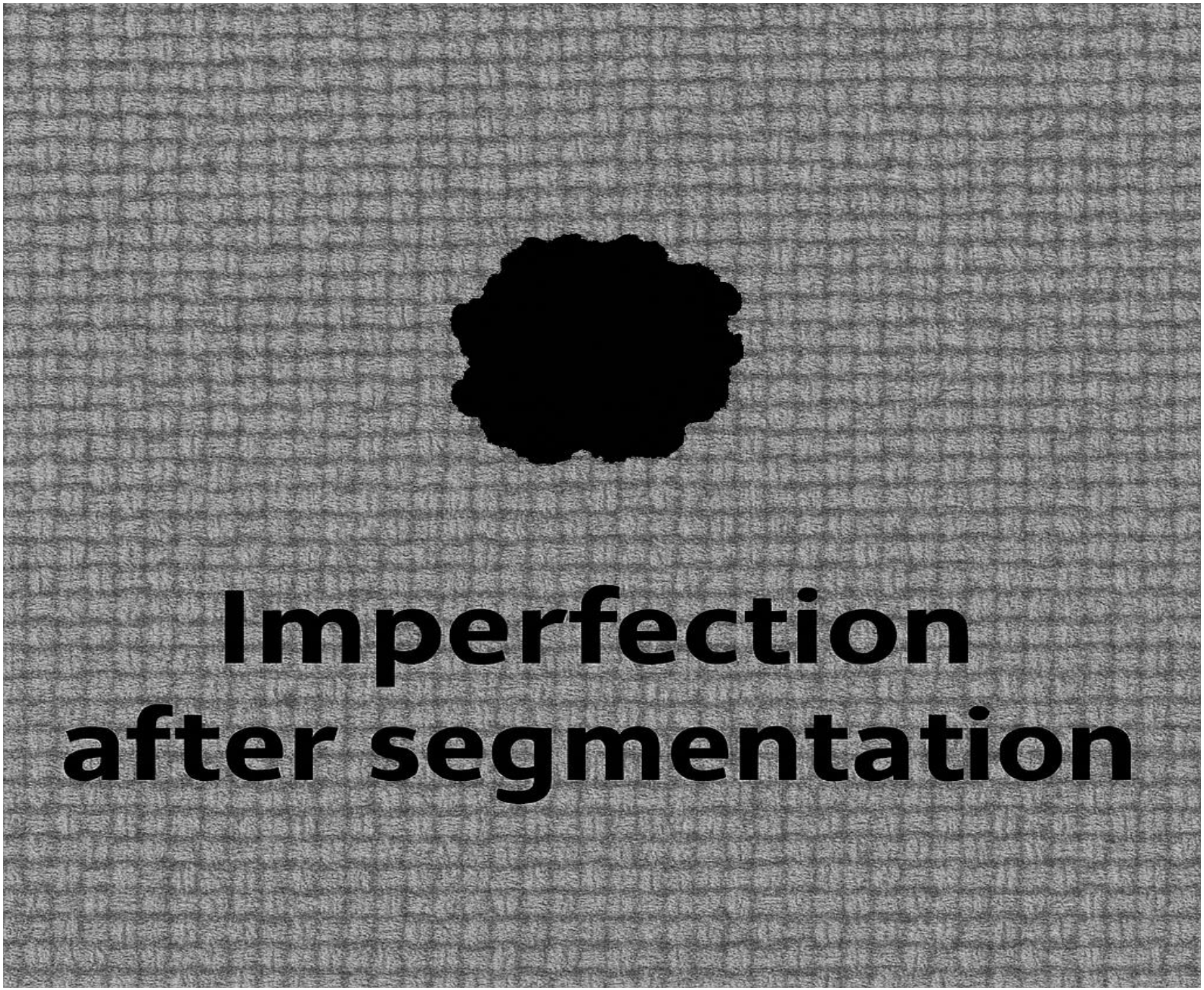


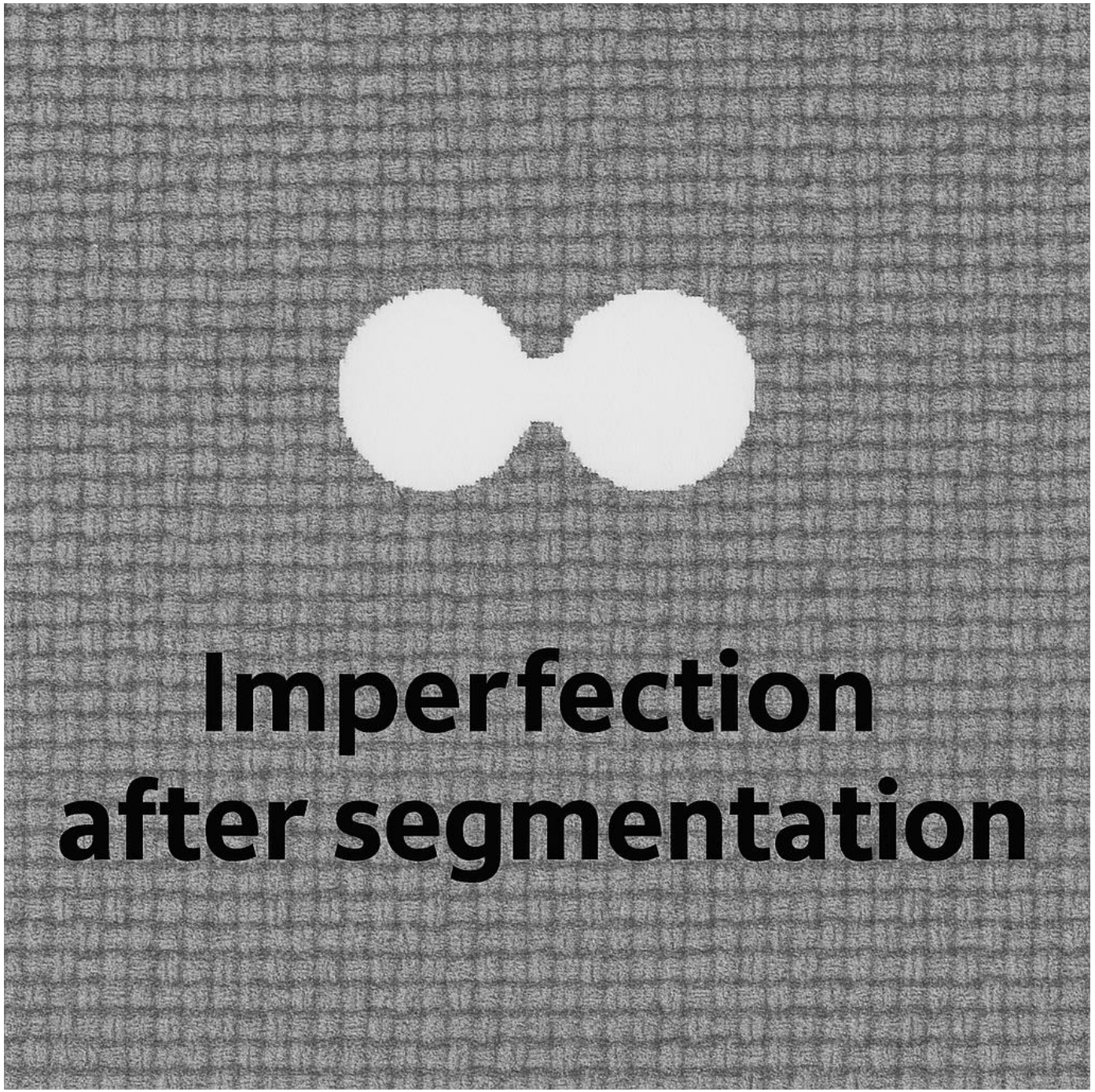
Composite Material Analysis



What Is Morphology?

1. Morphological image processing (or *morphology*) describes a range of image processing techniques that deal with the shape (or morphology) of features in an image
2. Morphological operations are typically applied to remove imperfections introduced during segmentation, and so typically operate on bi-level images


Imperfection
after segmentation


Imperfection
after segmentation

Document Image Cleaning and OCR

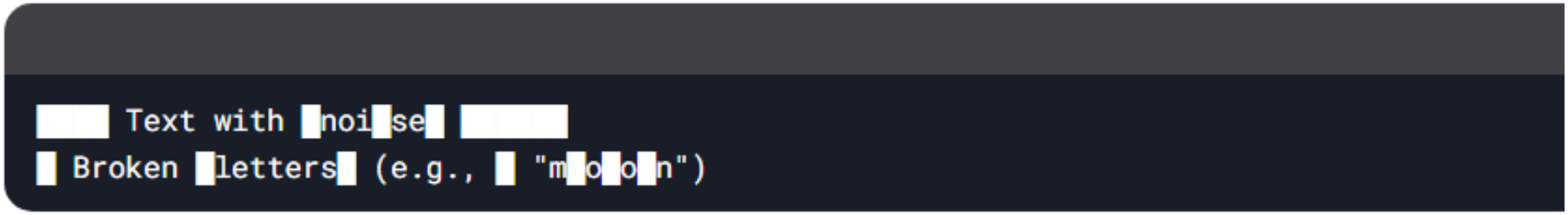
- Morphology removes **noise**, enhances **text structure**, and **connects broken characters** for better OCR (Optical Character Recognition).
- Used in restoring historical manuscripts or digitizing printed books.

Working on a noisy scanned page

1. **Original Image (Noisy)**

2. **Binarization (Thresholding)**

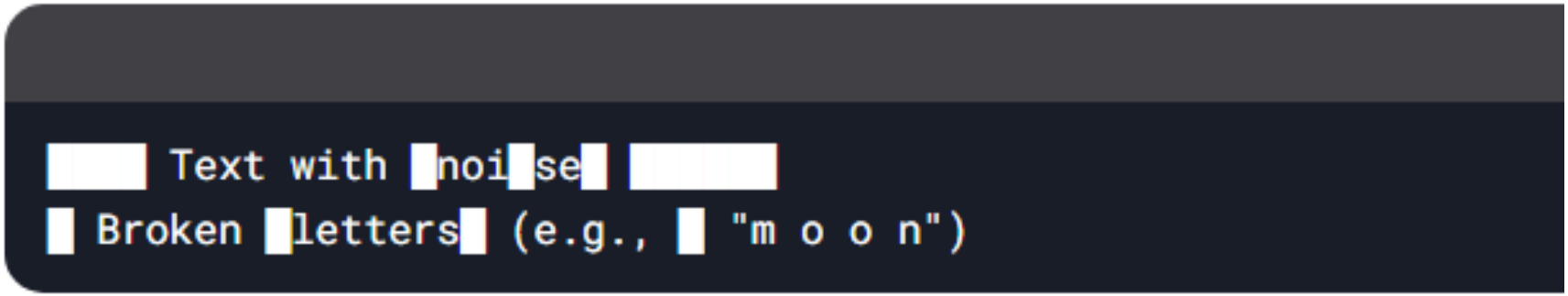
   Convert to black-and-white. Text becomes white (foreground), background black.



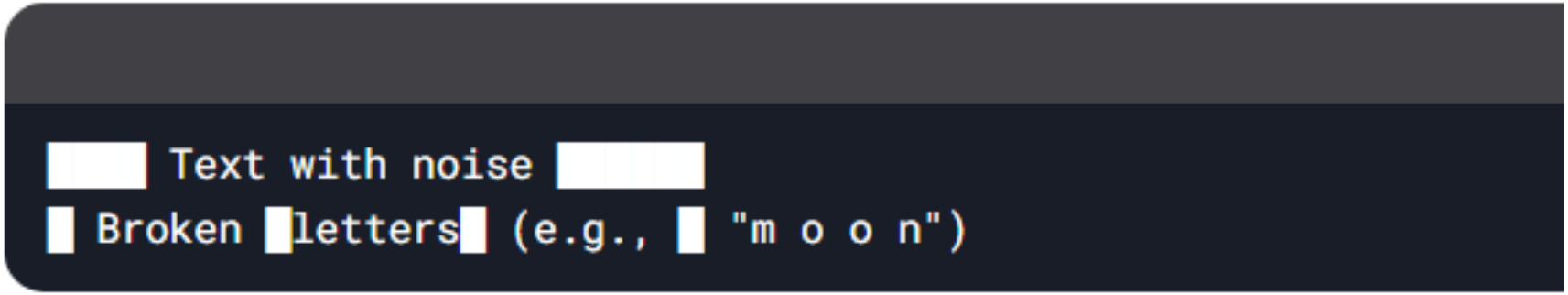
Working on a noisy scanned page

Morphological Opening (Erosion → Dilation)

- **Erosion:** Removes tiny white speckles by shrinking white regions.



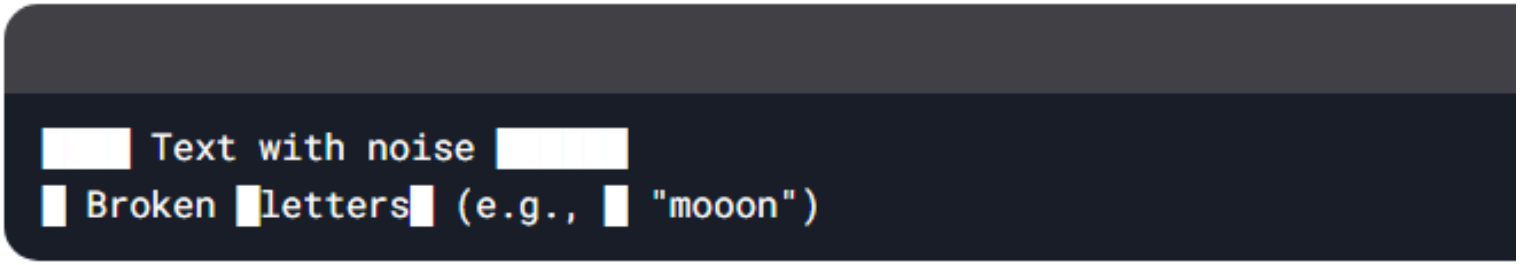
- **Dilation:** Restores text size but eliminates noise.



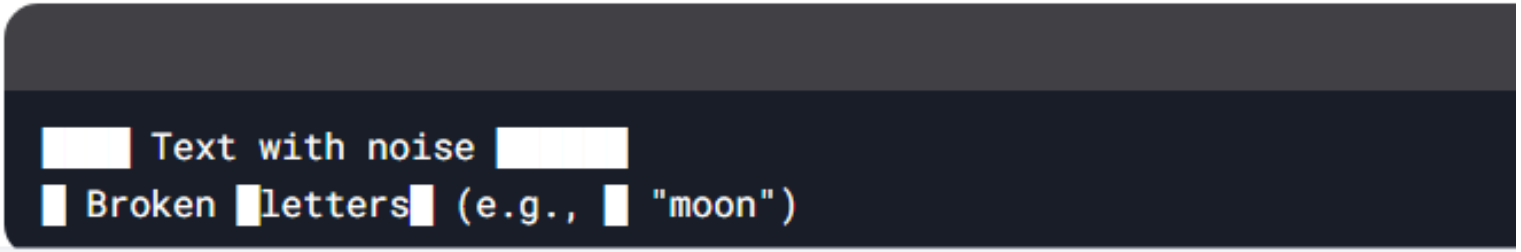
Working on a noisy scanned page

Morphological Closing (Dilation → Erosion)

- **Dilation:** Fills gaps in faint letters (e.g., connects "o"s in "moon").



- **Erosion:** Refines thickened text back to original shape.



OCR Improvement

Clean text ensures higher accuracy. For example, "m▒o▓o▓n" → "moon" instead of misread as "m0o0n" or "rn".

Example

Image after segmentation

Image after segmentation and morphological processing

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Image processing v/s Morphology

- “Image processing often focuses on pixel values — brightness, color, gradients. But morphology flips that. It asks: *what is the shape of the object?*
- *Where are the boundaries?*
- *How do structures grow, shrink, connect, or break apart?*”

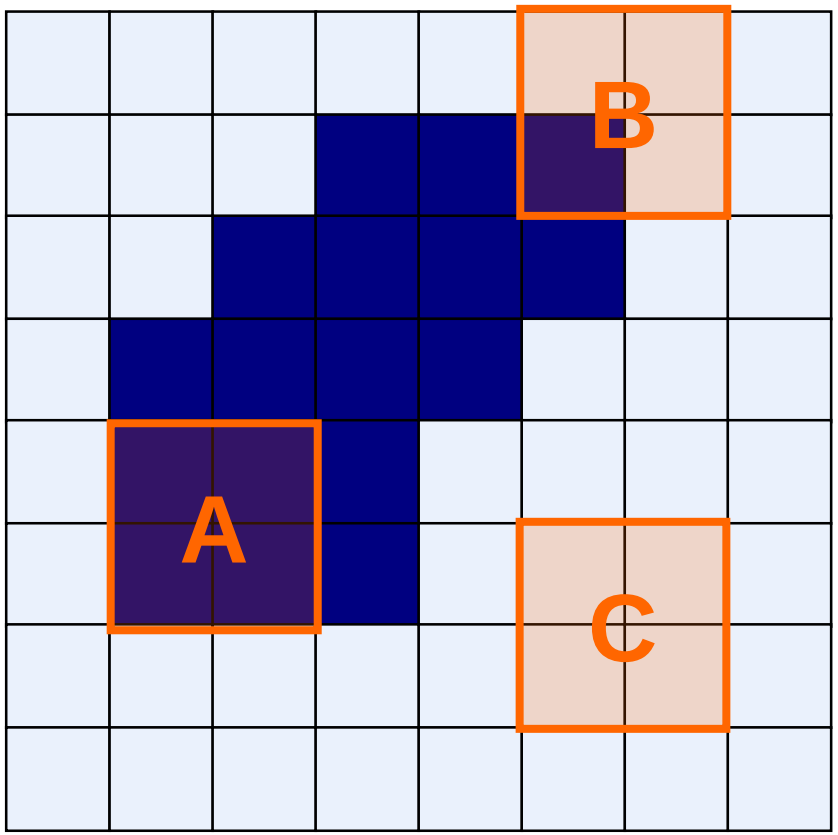
Image processing v/s Morphology

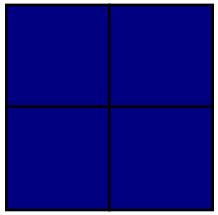
- Binary images as canvas.
- Pixels as building blocks of shape.
- Structuring element as a “probe” or stencil.
- **Erosion**: shrinking shapes
- **Dilation**: expanding them
- **Opening**: removing small objects/noise
- **Closing**: filling small holes or gaps

Application of Morphology as Game Changer

"What's one domain you care about — art, medicine, robotics — where shape understanding could change the game?"

Structuring Elements, Hits & Fits





Structuring Element

Fit: All *on pixels* in the structuring element cover *on pixels* in the image

Hit: Any *on pixel* in the structuring element covers an *on pixel* in the image

All morphological processing operations are based on these simple ideas

Structuring Elements

Structuring elements can be any size and make any shape

However, rectangular structuring elements with their origin at the middle pixel are convenient

1	1	1
1	**1**	1
1	1	1

0	1	0
1	**1**	1
0	1	0

0	0	1	0	0
0	1	1	1	0
1	1	**1**	1	1
0	1	1	1	0
0	0	1	0	0

Fitting & Hitting

0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	1	0	0	0	0	0	0	0
0	0	1	B	1	1	1	0	C	0	0	0
0	1	1	1	1	1	1	1	0	0	0	0
0	1	1	1	1	1	1	1	0	0	0	0
0	0	1	1	1	1	1	1	0	0	0	0
0	0	1	1	1	1	1	1	1	0	0	0
0	0	1	1	1	1	1	A	1	1	1	0
0	0	0	0	0	1	1	1	1	1	1	0
0	0	0	0	0	0	0	0	0	0	0	0

1	1	1
1	1	1
1	1	1

Structuring Element 1

0	1	0
1	1	1
0	1	0

Structuring Element 2

Fundamental Operations

1. Fundamentally morphological image processing is very like spatial filtering
2. The structuring element is moved across every pixel in the original image to give a pixel in a new processed image
3. The value of this new pixel depends on the operation performed
4. There are two basic morphological operations: **erosion** and **dilation**

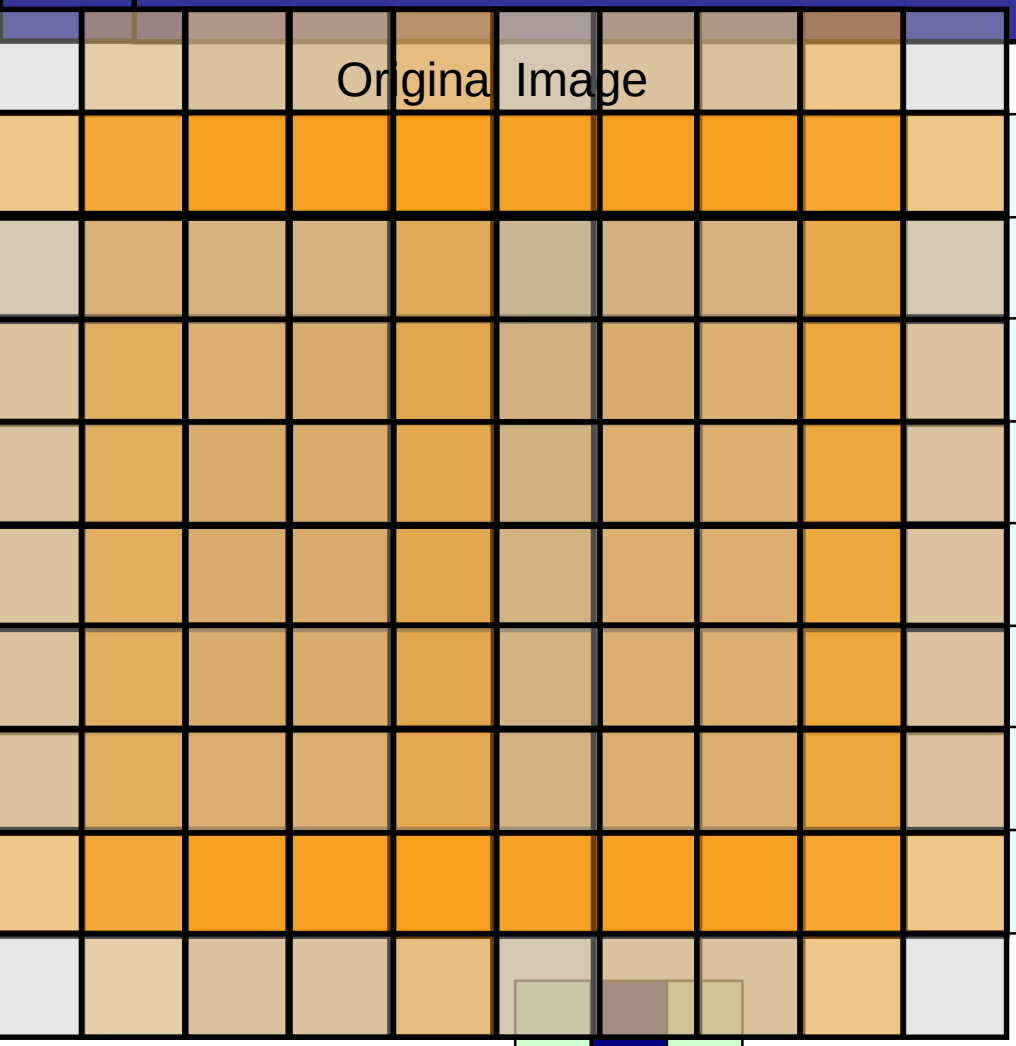
Erosion

Erosion of image f by structuring element s is given by $f \ominus s$

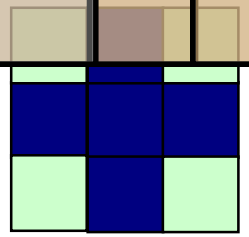
The structuring element s is positioned with its origin at (x, y) and the new pixel value is determined using the rule:

$$g(x,y) = \begin{cases} 1 \text{ if } s \text{ fits } f \\ 0 \text{ otherwise} \end{cases}$$

Erosion Example



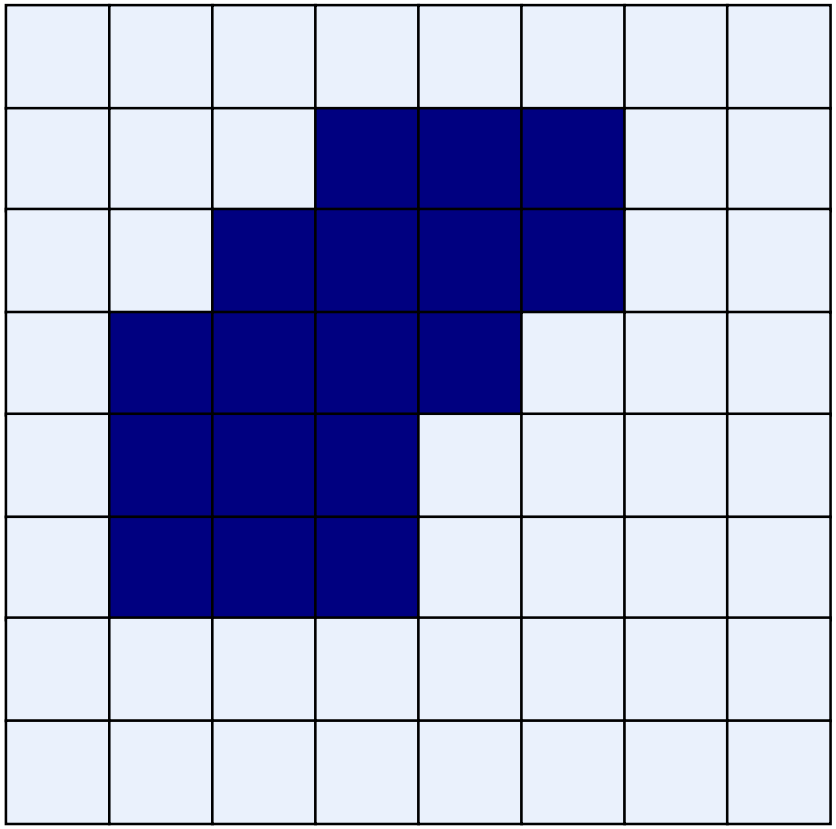
Processed Image With Eroded Pixels



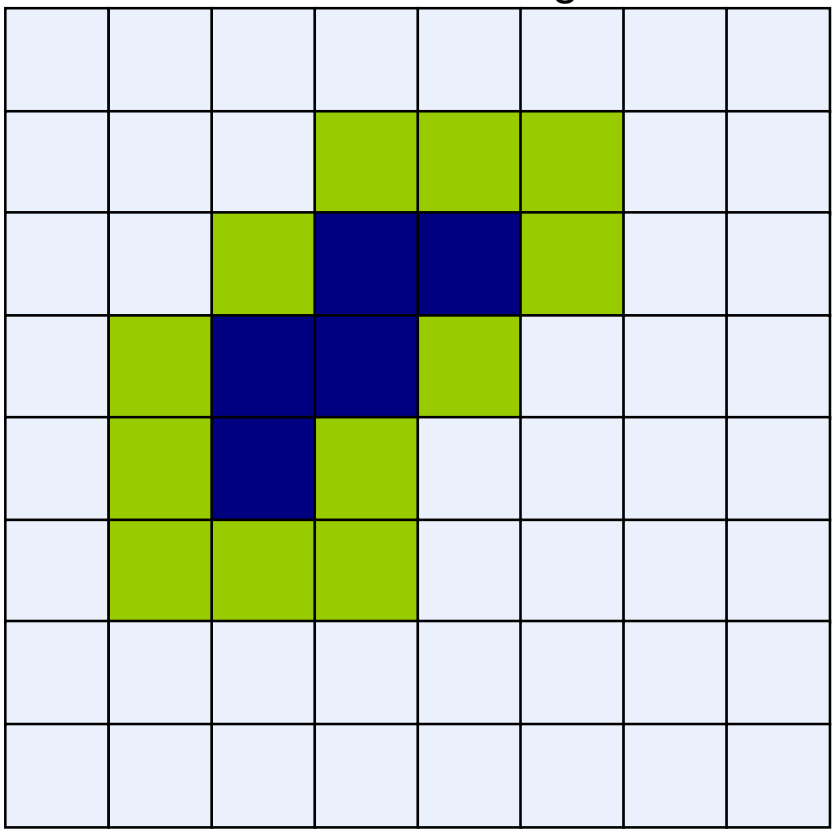
Structuring Element

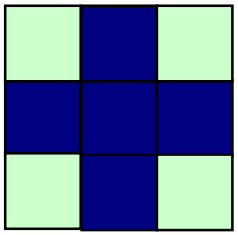
Erosion Example

Original Image



Processed Image

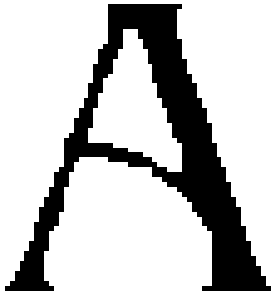




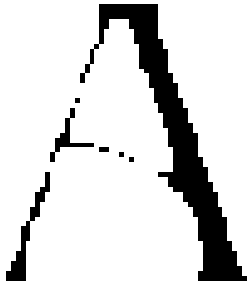
Structuring Element

Erosion Example 1

Original image

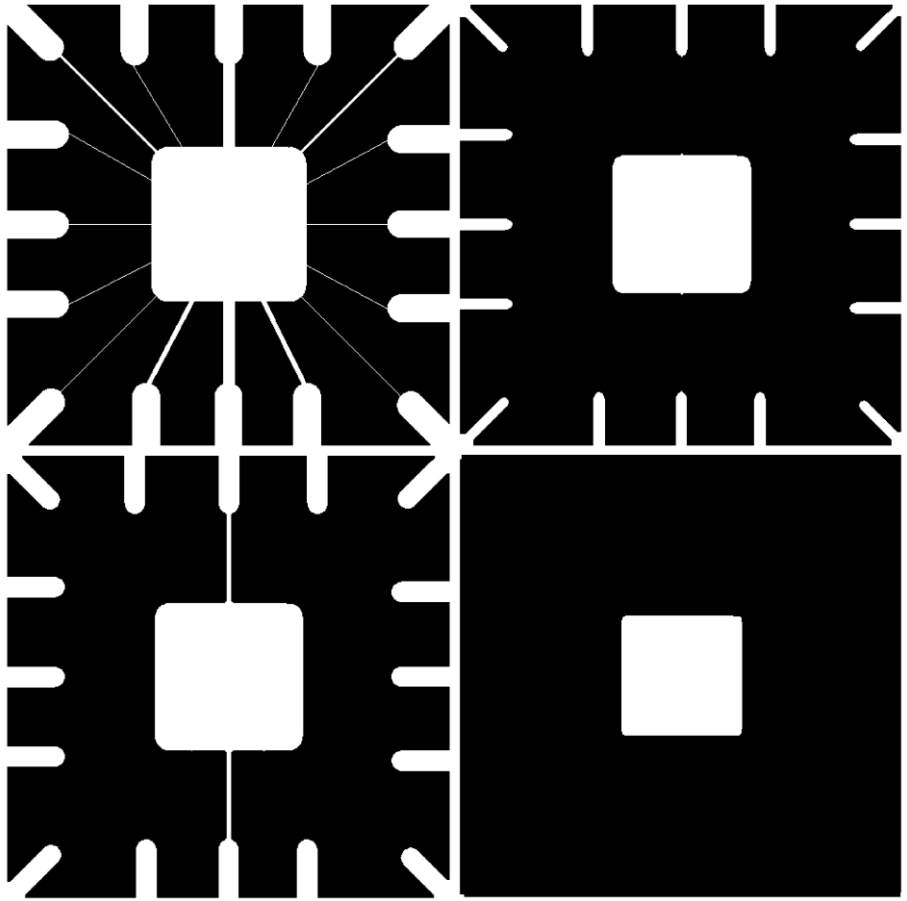


Erosion by 3*3 square structuring element



Erosion by 5*5 square structuring element

Erosion Example 2



Original image

After erosion with a disc of radius 10

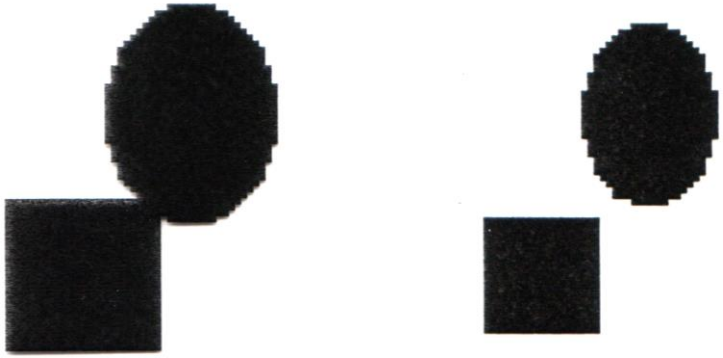
After erosion with a disc of radius 5

After erosion with a disc of radius 20

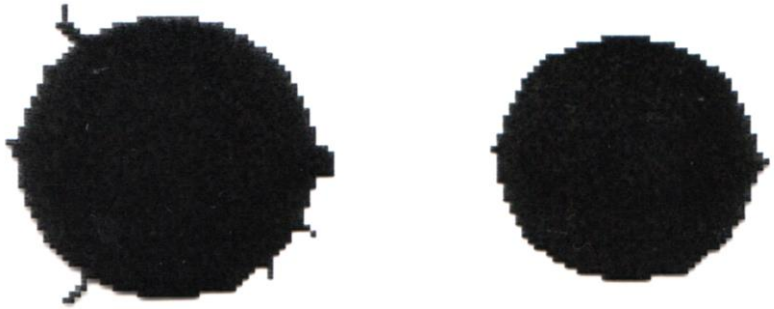
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

What Is Erosion For?

Erosion can split apart joined objects



Erosion can strip away extrusions



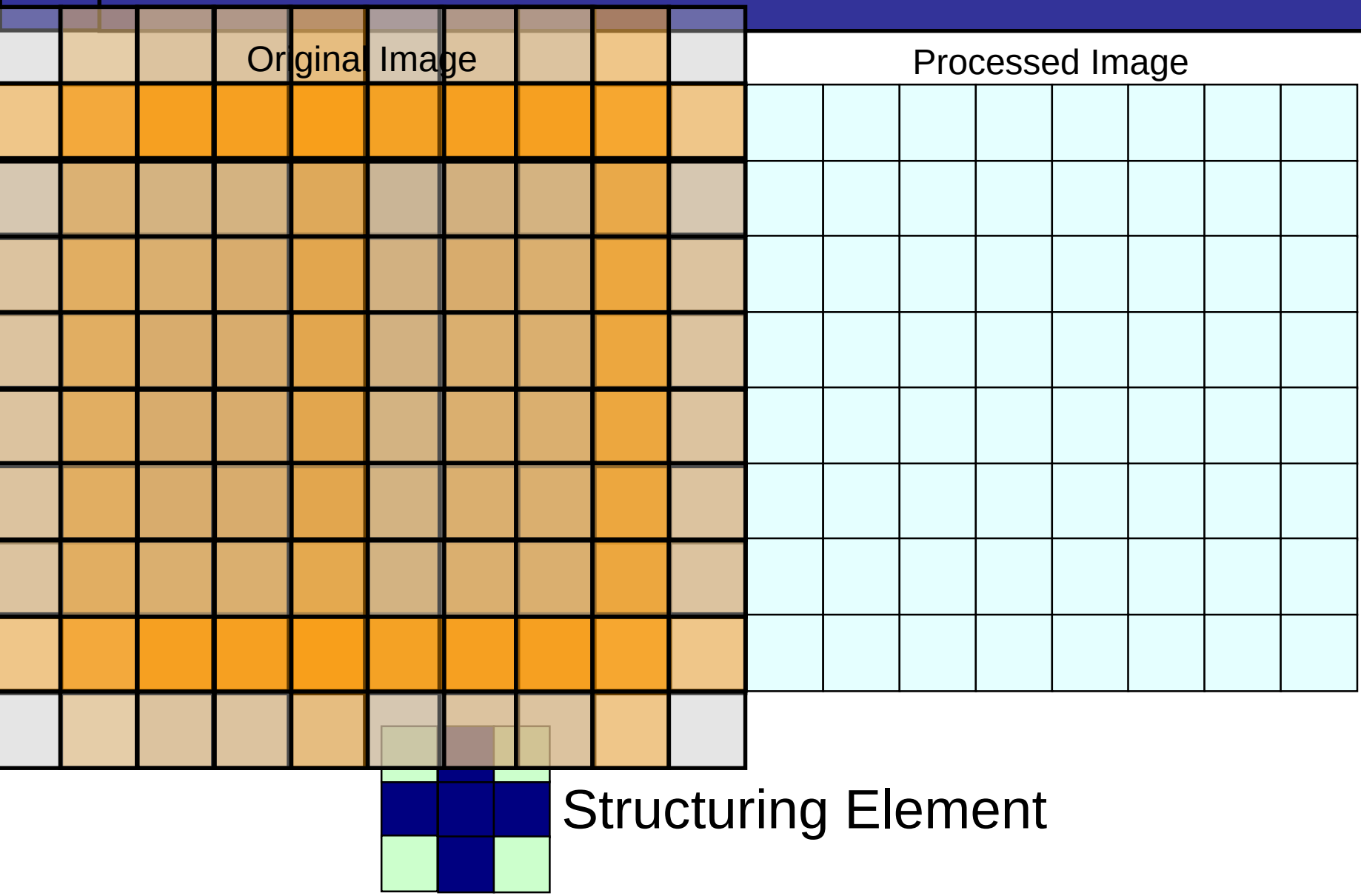
Watch out: Erosion shrinks objects

Dilation

1. Dilation of image f by structuring element s is given by $f \oplus s$
2. The structuring element s is positioned with its origin at (x, y) and the new pixel value is determined using the rule:

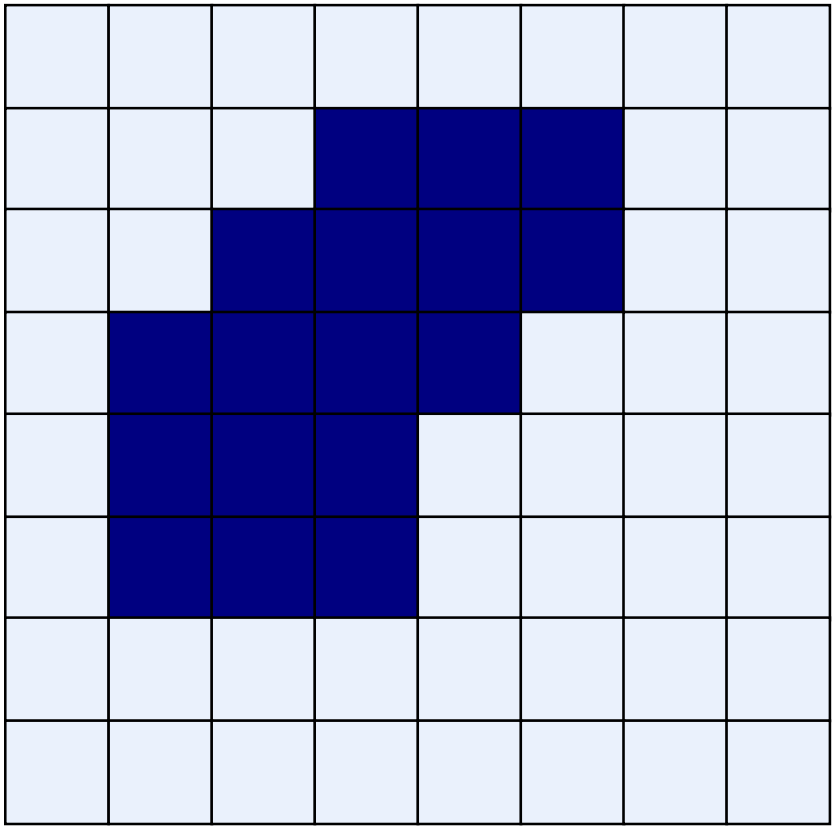
$$g(x,y) = \begin{cases} 1 \text{ if } s \text{ hits } f \\ 0 \text{ otherwise} \end{cases}$$

Dilation Example

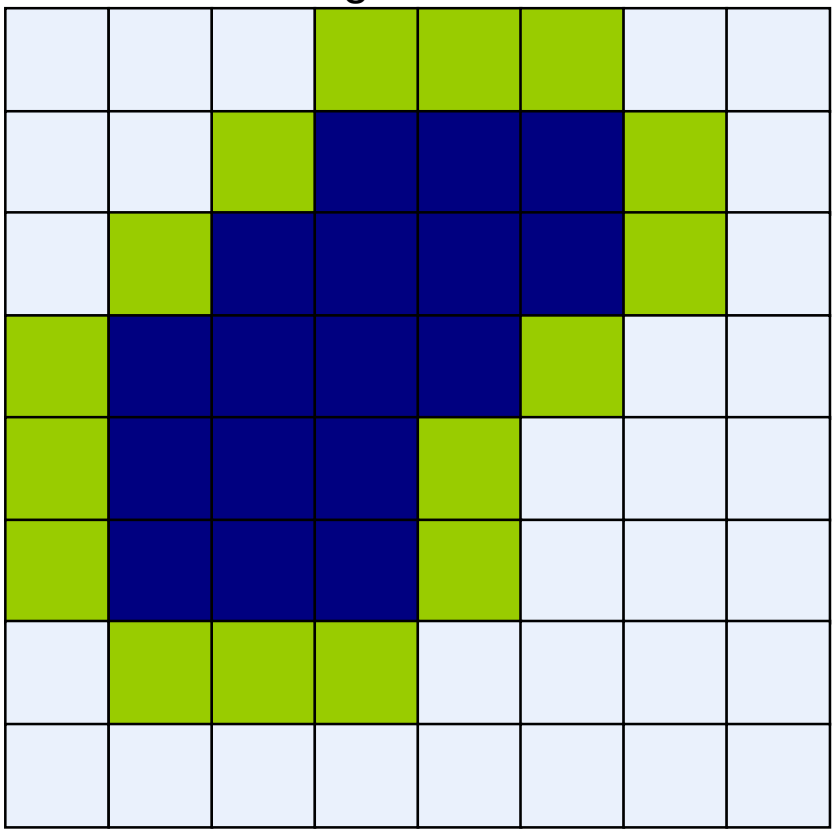


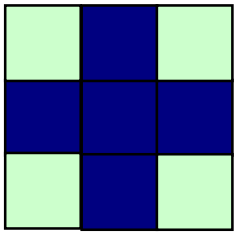
Dilation Example

Original Image



Processed Image With Dilated Pixels





Structuring Element

Dilation Example 1

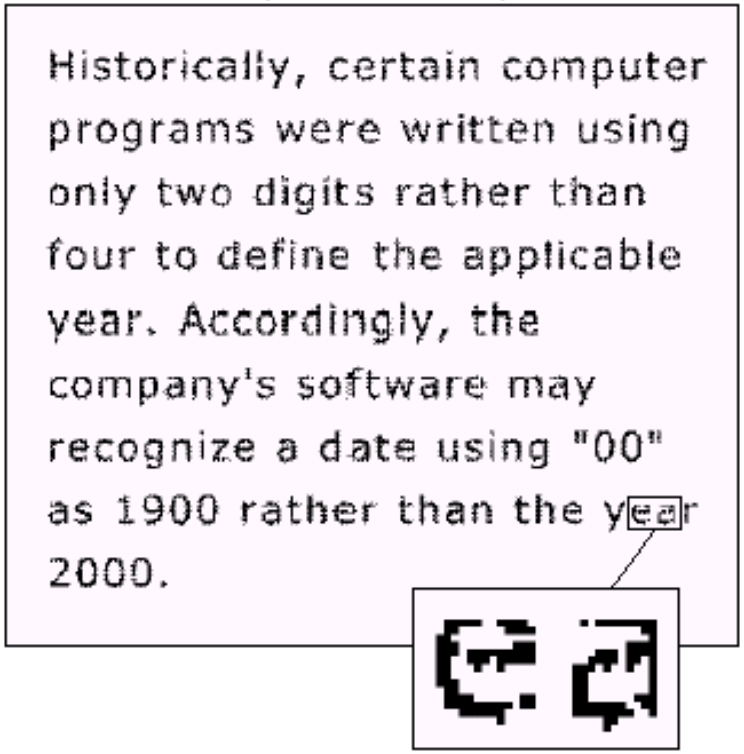
Original image

Dilation by 3*3 square structuring element

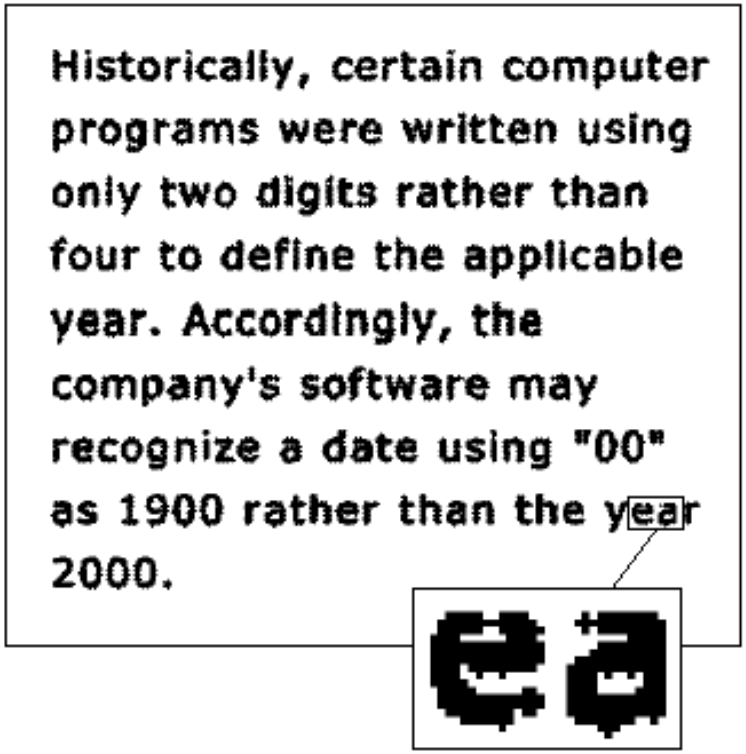
Dilation by 5*5 square structuring element

Dilation Example 2

Original image



After dilation



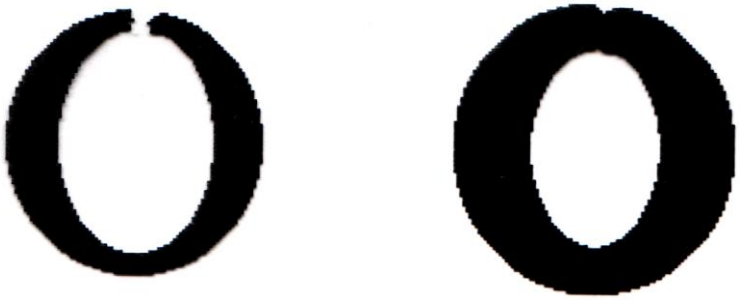
0	1	0
1	1	1
0	1	0

Structuring element

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

What is Dilation for?

Dilation can repair breaks



Dilation can repair intrusions

Watch out: Dilation enlarges objects

Compound Operations

More interesting morphological operations can be performed by performing combinations of erosions and dilations

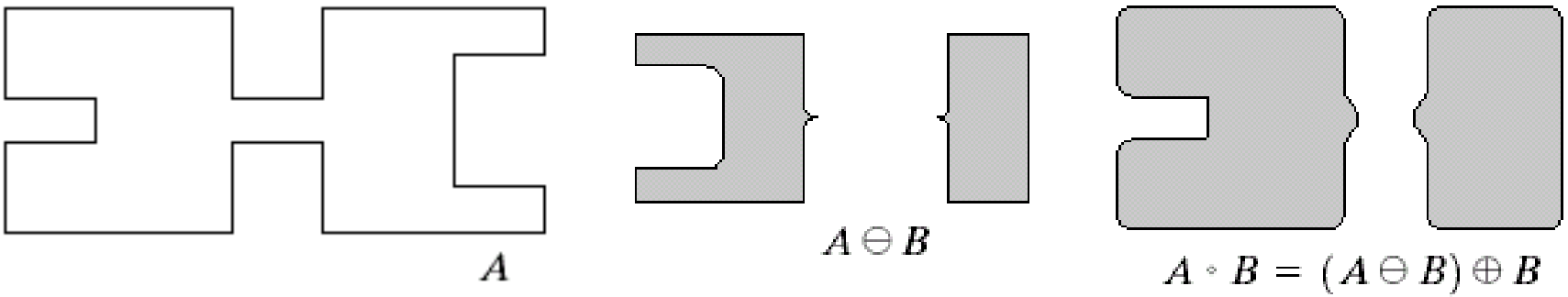
The most widely used of these *compound operations* are:

- Opening
- Closing

Opening

The opening of image f by structuring element s, denoted $f \circ s$ is simply an erosion followed by a dilation

$$f \circ s = (f \ominus s) \oplus s$$



Original shape | After erosion | After dilation (opening)

Note a disc shaped structuring element is used

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Opening Example

Original Image

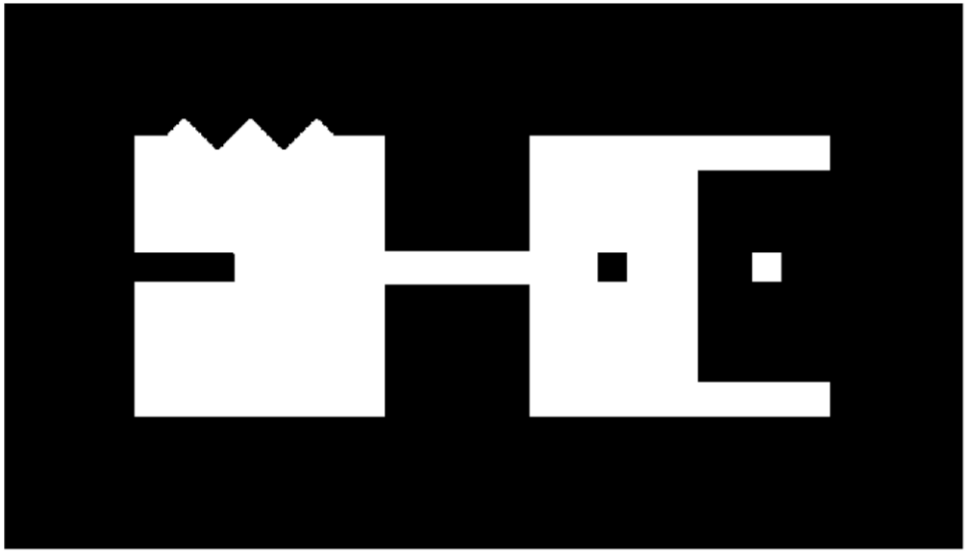
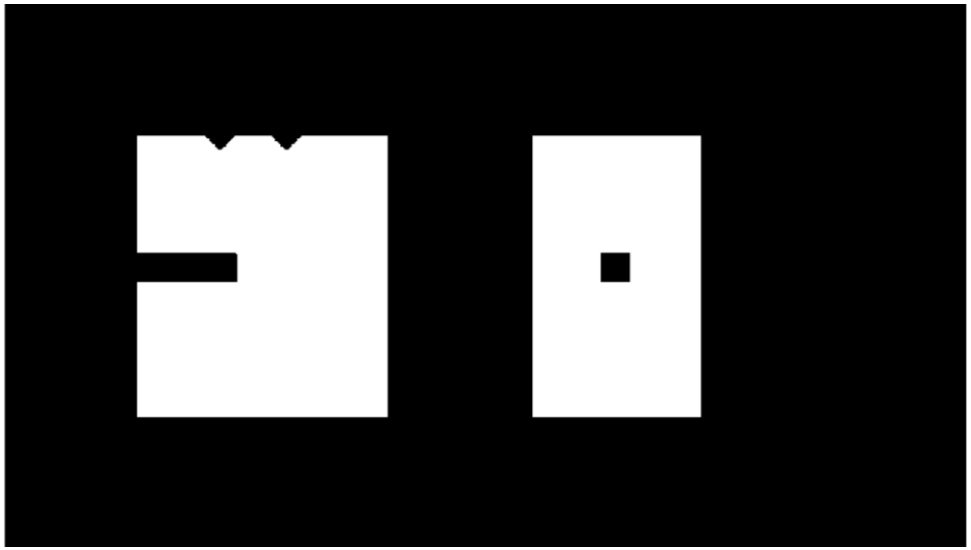


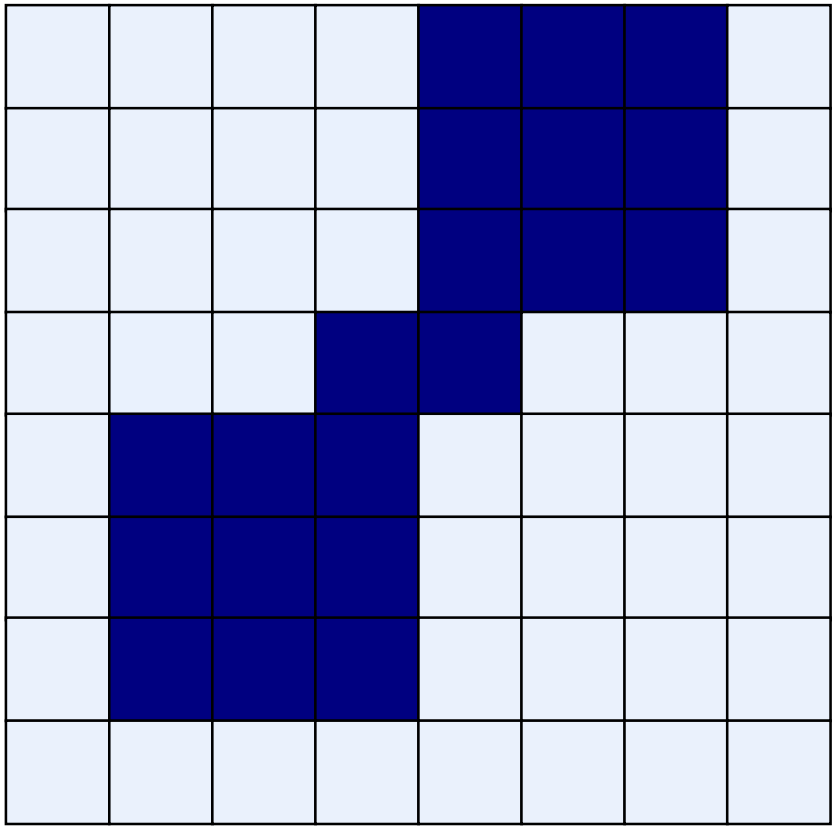
Image After Opening



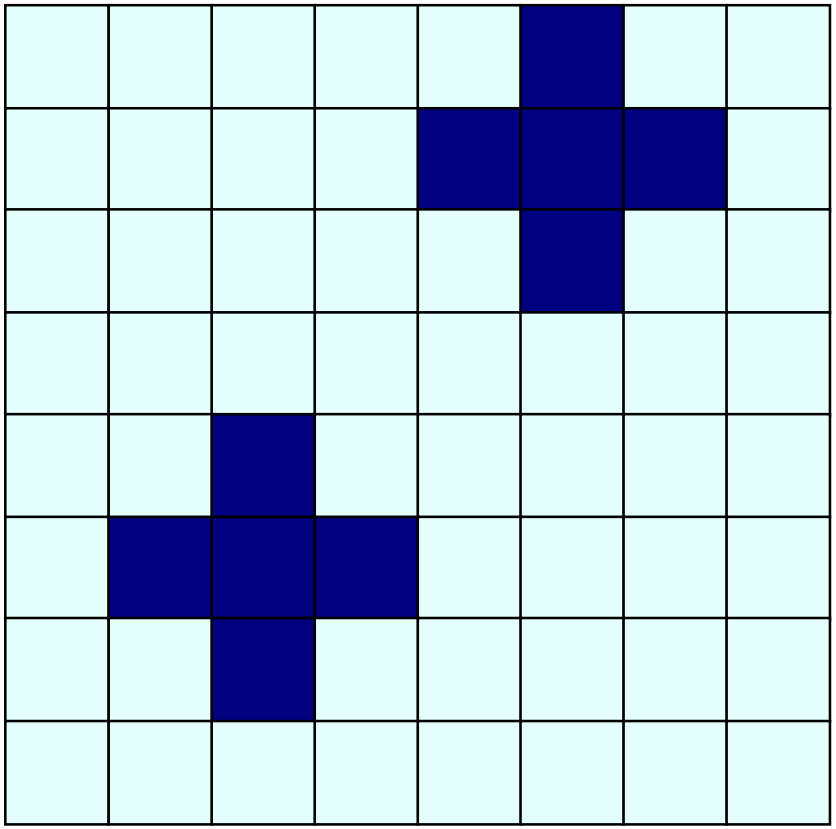
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

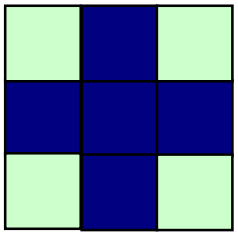
Opening Example

Original Image



Processed Image



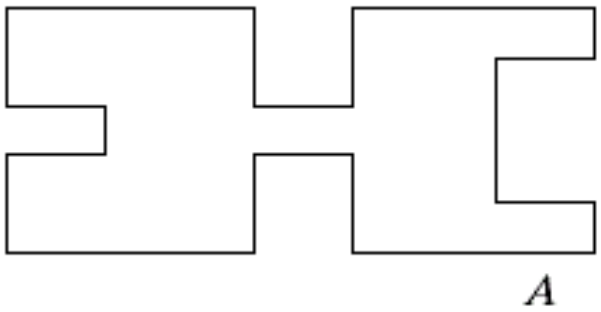


Structuring Element

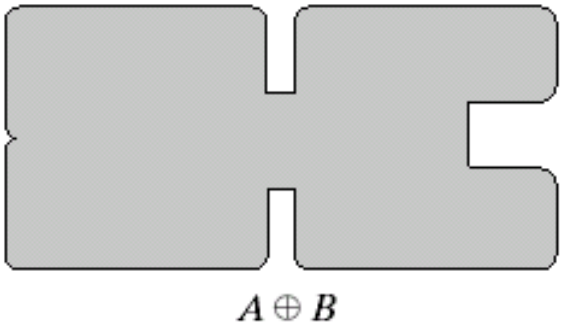
Closing

The closing of image f by structuring element s, denoted $f \bullet s$ is simply a dilation followed by an erosion

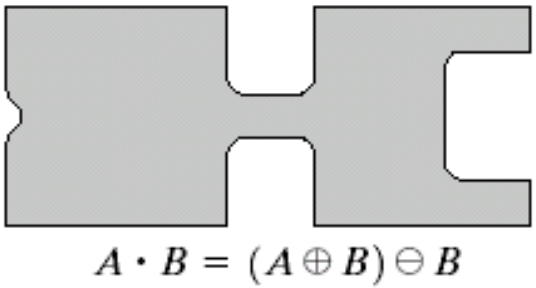
$$f \bullet s = (f \oplus s) \ominus s$$



Original shape



After dilation



After erosion (closing)

Note a disc shaped structuring element is used

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Closing Example

Original Image

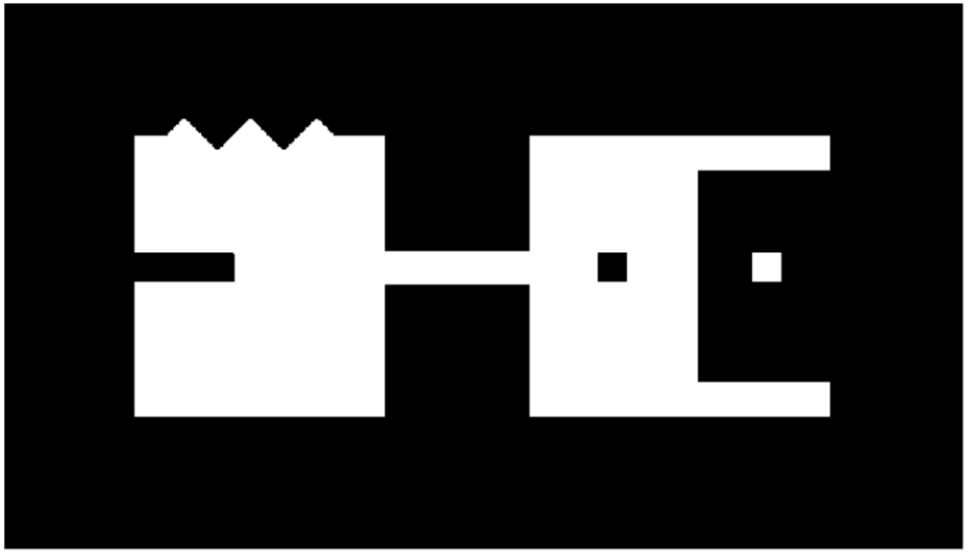
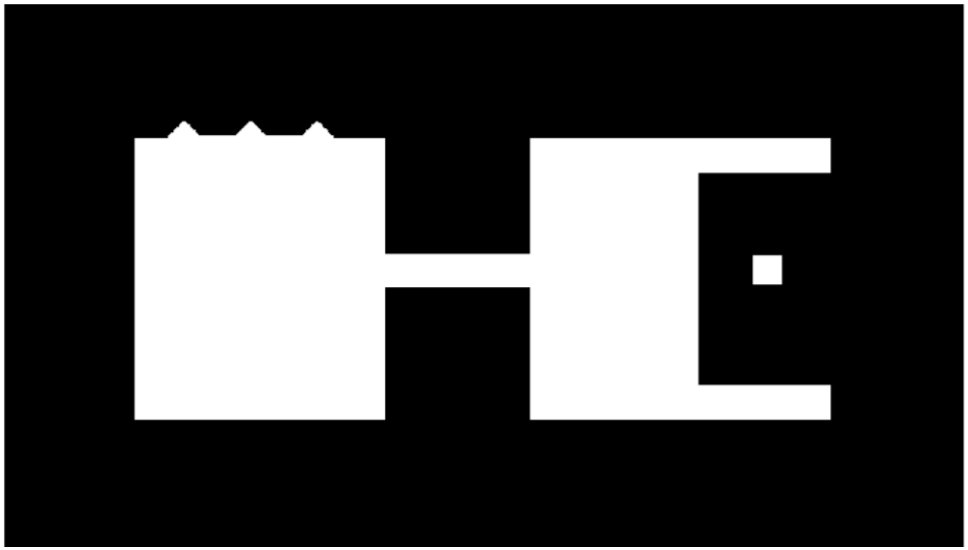
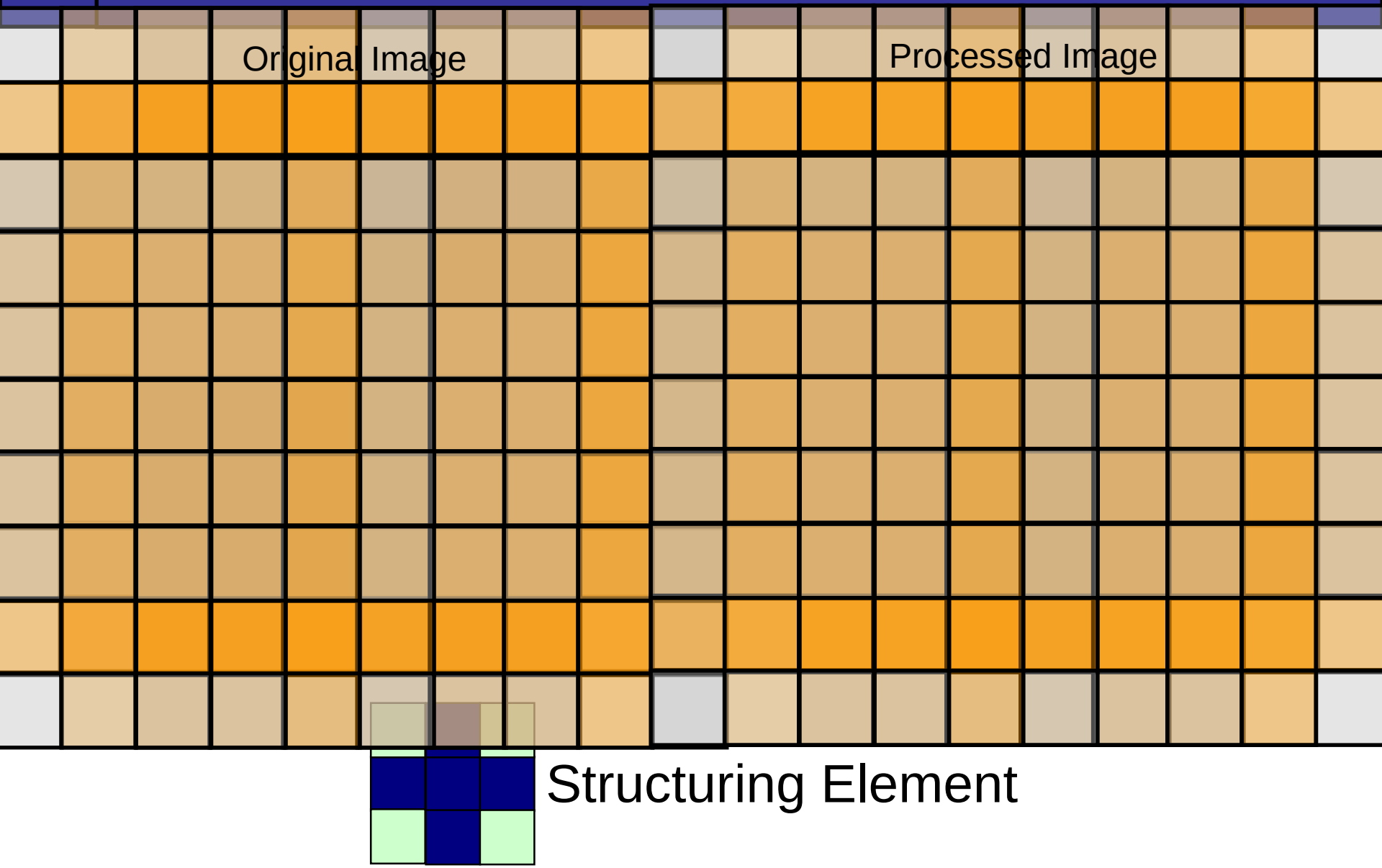


Image After Closing



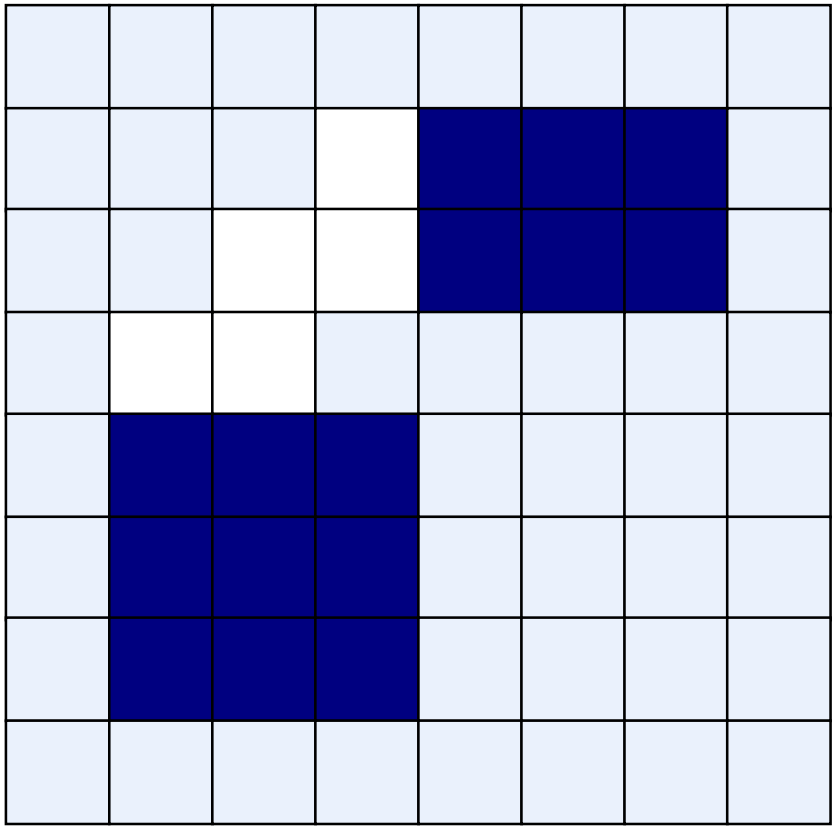
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Closing Example

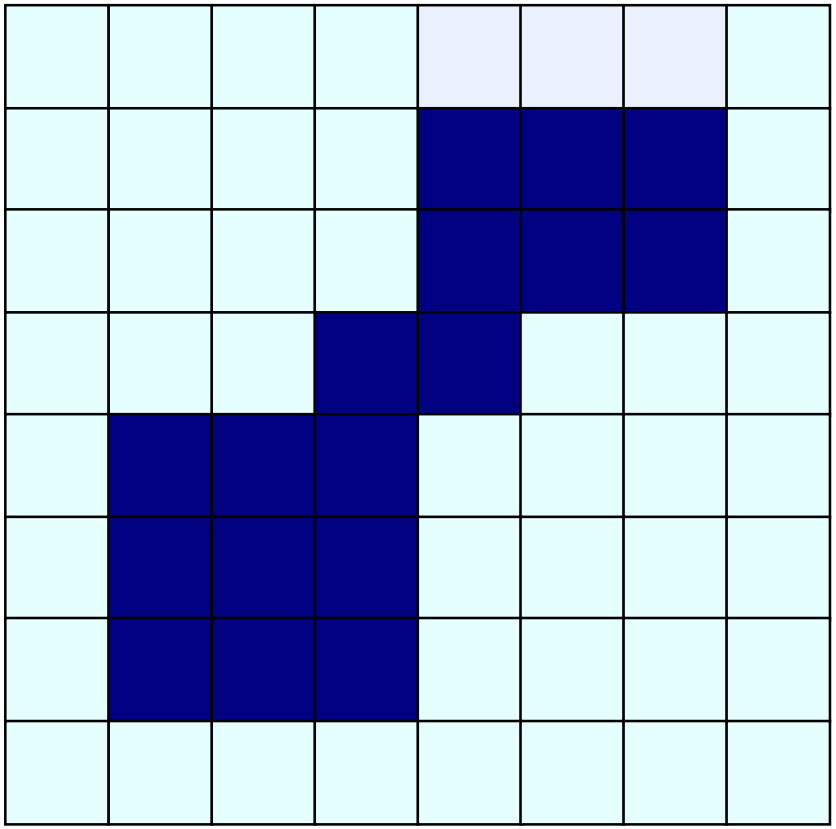


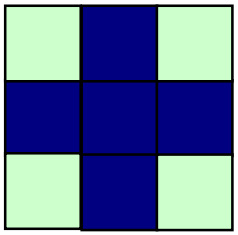
Closing Example

Original Image



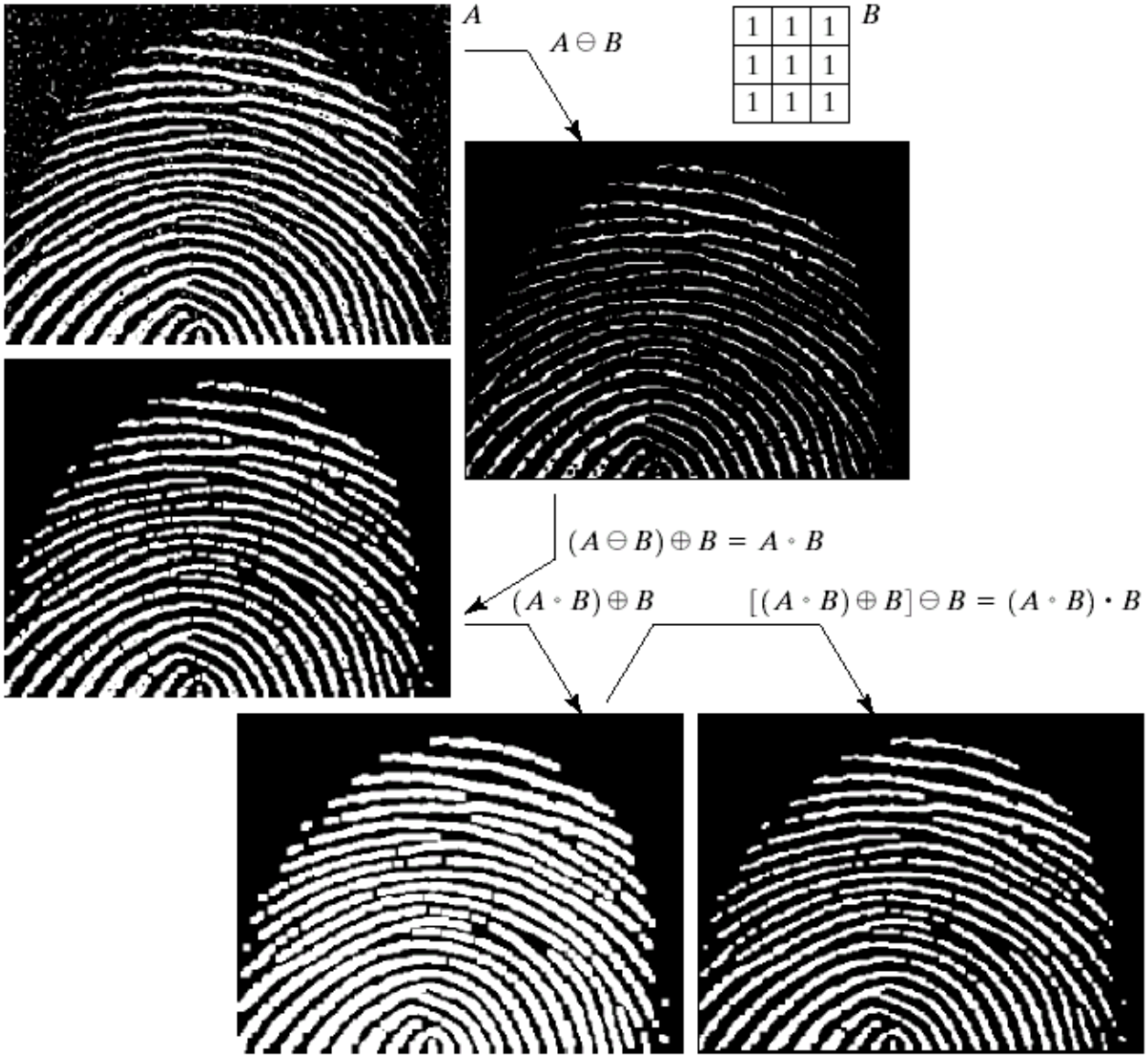
Processed Image





Structuring Element

Morphological Processing Example



Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Morphological Algorithms

Using the simple technique we have looked at so far we can begin to consider some more interesting morphological algorithms

We will look at:

- Boundary extraction
- Region filling

There are lots of others as well though:

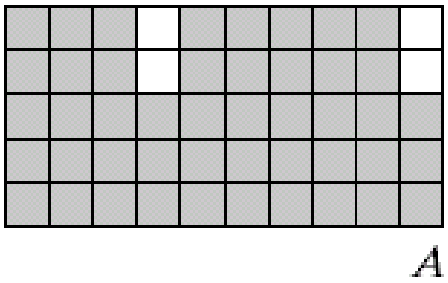
- Extraction of connected components
- Thinning/thickening
- Skeletonisation

Boundary Extraction

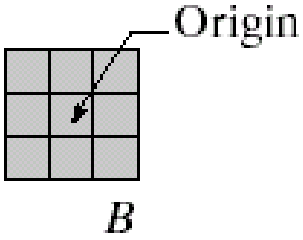
Extracting the boundary (or outline) of an object is often extremely useful

The boundary can be given simply as

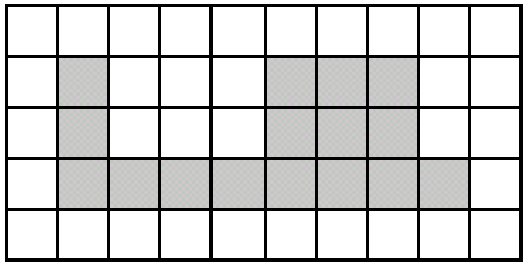
$$\beta(A) = A - (A \ominus B)$$



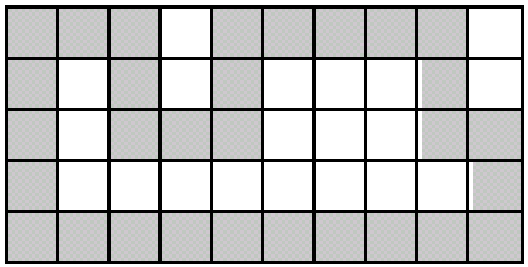
A



B



$A \ominus B$

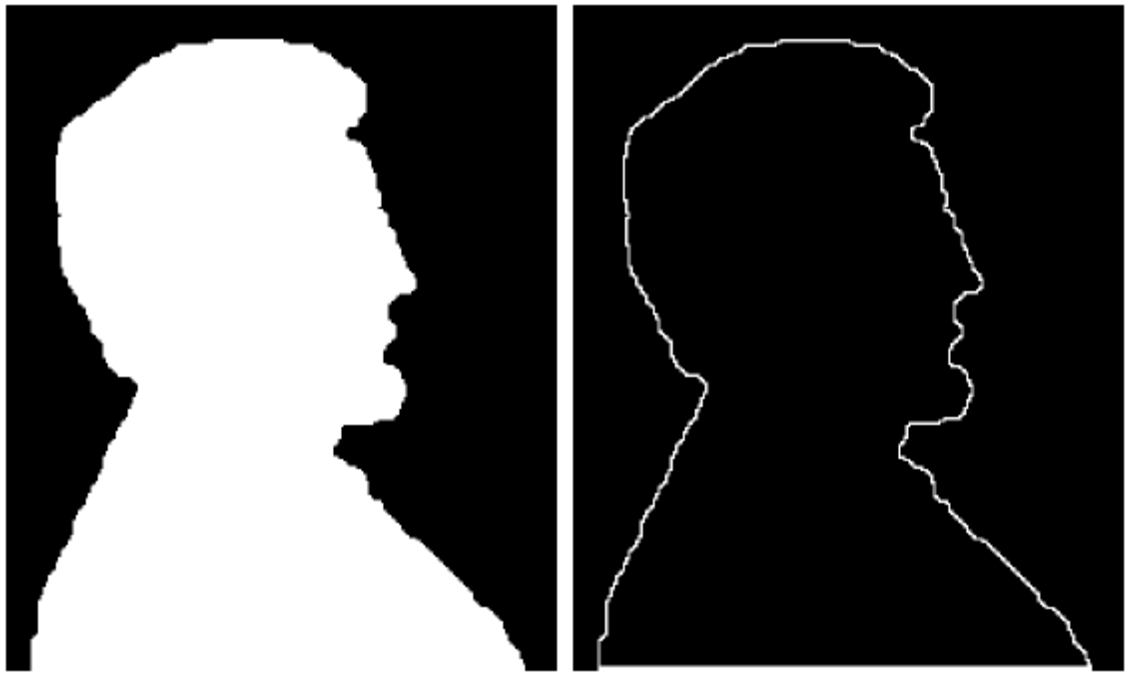


$\beta(A)$

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Boundary Extraction Example

A simple image and the result of performing boundary extraction using a square 3*3 structuring element



Original Image Extracted Boundary

Images taken from Gonzalez & Woods, Digital Image Processing (2002)